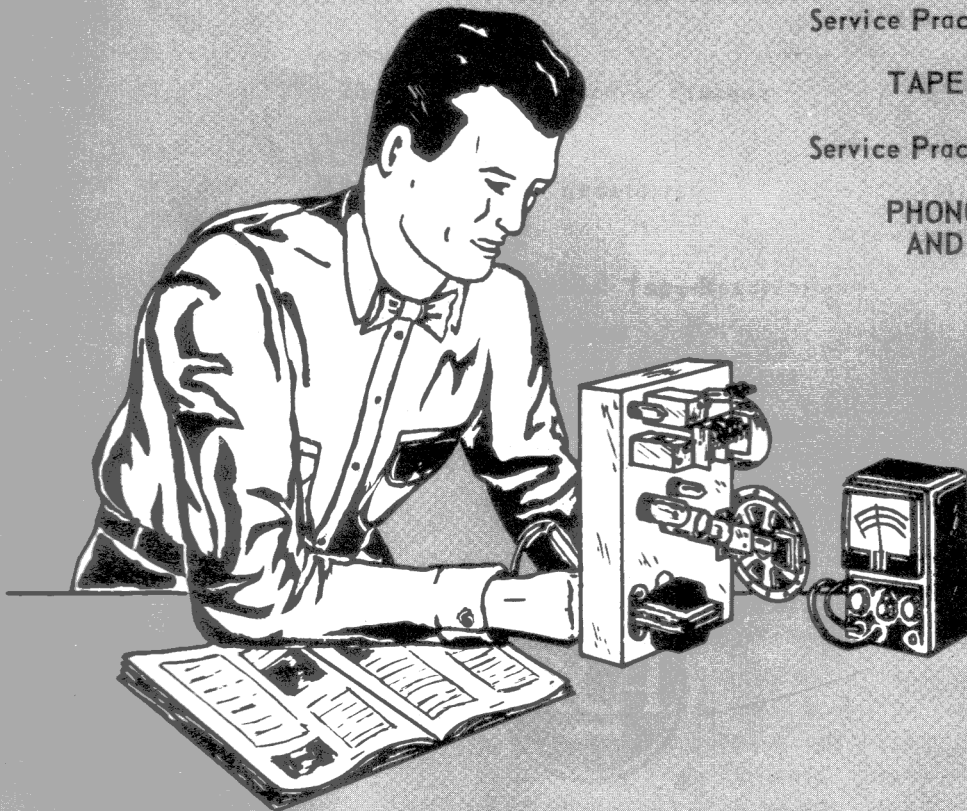


Study Group 12

ELECTRONIC FUNDAMENTALS



Service Practices 23:

TAPE RECORDERS

Service Practices 24:

PHONO PLAYERS
AND PICKUPS



RCA INSTITUTES, INC.

A SERVICE OF RADIO CORPORATION OF AMERICA

New York.

N. Y.

ELECTRONIC FUNDAMENTALS

SERVICE PRACTICES 23

TAPE RECORDERS

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Service Practices 23

INTRODUCTION

Tape recorders and other recorders enable us to record sounds for later reproduction. An early recorder, based upon the work of Thomas Edison, is shown in Fig. 23-1. The sound, focused by a horn, causes a disk to vibrate. The stylus attached to the disk cuts into the wax cylinder, which rotates and moves back and forth. When the sound pushes the disk harder, the stylus cuts deeper. As a result, the cylinder has a

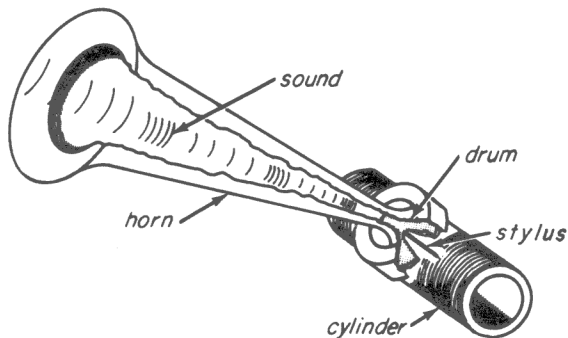


Fig. 23-1

spiral groove that varies in depth in a pattern corresponding to the waves of sound that push on the disk. The cross section of the cylinder in Fig. 23-2 shows a part of the groove in the cylinder and the pattern in it.

The sound is reproduced by the reverse process. A cylinder in which grooves have already been cut is placed on the spindle. The stylus on the disk is set into the beginning of the groove on the cylinder and the cylinder is made to rotate. The stylus moves up and down in the groove and the disk vibrates in a pattern corresponding to the groove. The vibrating disk pushes air waves into the megaphone. These air waves, when they reach the listener's eardrums produce the sensation of sound.

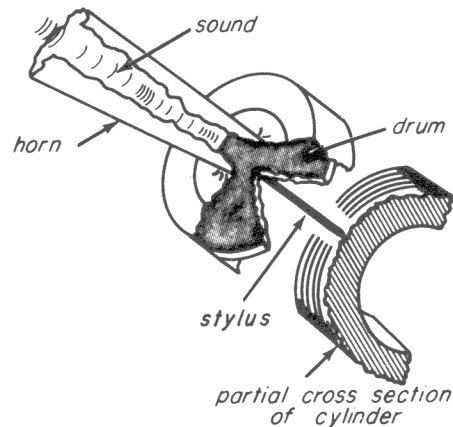


Fig. 23-2

Later recorders and record players have used the same fundamental principle, but modified the apparatus for improved performance. The cylinder on the Edison machine has been replaced by the wax disk that you have seen. This wax disk, called a *record* because it is a record of sound has been made by a mass production process that has made it possible for practically everyone to have access to recorded sound. The grooves in records are made narrower and wider instead of deeper and shallower.

Many people today record sounds they wish to preserve by a simple process they can use right in their own homes. They use *magnetic tape* recorders, which are the main subject of this booklet.

23-1. QUALITY OF RECORDED SOUND

The factors that limit the quality of recorded sound are the range of tones produced, the range of loudness produced, freedom from distortion, and freedom from noise.

Early mechanical disk recorders could not record the heavy bass tones. Therefore, records sounded tinny. They could not record the very high-pitched tones, either. Therefore, records sounded muffled. They could record the middle tones. This is sufficient

for *intelligibility* (to recognize spoken words) but not for exact reproduction of tonal quality. Listening to an early mechanical recording, you would understand spoken words. You probably would not recognize a voice even though it belonged to someone you were acquainted with.

Edison's process was mechanical. It employed no electronic sound amplifier. Early disk recorders were mechanical, too. Mechanical recorders were not well suited to the faithful reproduction of tone quality, because they could not concentrate the force of the sound vibrations upon the needle equally for all tones.

Low tones are slow vibrations. A powerful low tone moves a large quantity of air slowly. A small portion of this air (about the size of the recorder's drum), although it represents the *motion* of the low tone, does not contain much power. Air moved slowly is moved gently; much must be moved to put forth power. A large drum would be needed to receive full power from slow air. The slow moving currents of air, vibrating to the rhythm of a low tone, did not push the little recorder drum hard enough; the drum and needle could not capture enough low-note power from the air to equal the power captured from the middle tone air currents.

High-note power is different. High tones are fast vibrations. Less air is moved, but moved many times. There was not much difficulty about concentrating strong enough high frequency vibrations (high tones) upon the needle. The problem with high tones was to make the needle move as fast as the vibrations tried to push it. This it would not do.

The range of loudness the mechanical process could produce also was limited. The tiny indentations in the track of the record did not produce enough air vibrations to get many of the sounds they were supposed to represent.

In early recordings, the needle did not have enough room in its track to move the full distance required to complete the motion of strong sound vibrations. These vibrations were distorted. Also, there was much noise in the form of needle scratch.

Mechanical recording presented other difficulties, too. For example, the great horn

that served to gather the waves of sound in air and to funnel them down upon the drum was an awkward thing to work with. It was especially difficult to record the music of an orchestra. The mouth of the horn was not large enough to easily gather in the sounds from all the instruments, spread (as they are in an orchestra) over a large area. To overcome this difficulty, musicians had to be piled up vertically instead of spread out horizontally. They sat upon a row of steps, one behind the other, in front of the horn.

In time, an electrical disk-recording process was developed. Most sound quality limitations were overcome, although not all at once, through the development of the electrical system. In the electrical system, sound vibrations are gathered by microphones, instead of by a horn. Many microphones can be employed and placed where needed. Musicians no longer have to sit on steps. The sound vibrations are converted to electric currents and amplified electrically.

A microphone responds to low tones better than does a mechanical disk fastened to the needle in the Edison recorder. It took a hefty gust of air to move the disk, push the needle, and cut the wax. The equivalent of the disk in the microphone (most mikes have some part that gets pushed by the air currents) has less work to do. It doesn't have to cut wax. When it vibrates, it merely generates a tiny electric current. A very weak low-tone air-pressure change can cause it to do that. A microphone does not respond equally well to all sound frequencies. Once picked up, electrical impulses corresponding to the sounds can be amplified. If desired, one frequency can be amplified more than another to have all come out of the amplifier equally strengthened.

In practice, high-pitched tones are *made louder* when a recording is made. This is called *preemphasis*. If the record were played back in a recorder that did not take this preemphasis into account, the high-pitched sounds would be far too loud. However, when the record is played on a recorder, the needle makes a scratch noise. This is also a high-pitched noise, but not so loud as the preemphasized high-pitched sound on the record. Thus, when all high-pitched

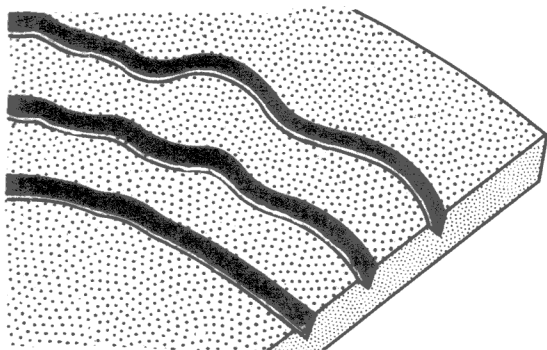


Fig. 23-3

sound and noise is reduced by the process called *equalization*, the desired sound is brought back to the correct level and the noise is much reduced.

Also, during recording, any low-pitched sounds that are very loud are made weaker. Low-pitched tones cause a wide swing of the cutting needle, and loud low-pitched tones cause the needle to swing so far that the cut might spread into the next groove of the record (Fig. 23-3). As a result of these and other considerations, the phonograph record of today generally produces less base and more treble than it should provide if it is to give an accurate reproduction of the original music. This difference is made up for in the phonograph on which these records are played. Here, the low tones are amplified more and the high tones less, by means of equalization. Thus, equalization in the recorder's circuit restores all tones to the correct relative amplitude.

The mechanical disk was not able to move rapidly enough to record a quick vibration. However, in electronic recording, the rapid vibrations are electronically amplified and sent from an amplifier to a cutting head with a greatly reduced mass. As a result, the needle responds even to high frequency vibrations. Even a whisper arrives at the needle in sufficient strength to make it move. And this does not necessarily cause a whisper to sound as loud as a shout; the shout arrives even stronger.

The ability of a recording system to reproduce a wide range of sound volume extending from a whisper to a shout is known as the system's ability to reproduce a wide *dynamic range* of volume.

Needle scratch noise limits dynamic range. If the material the disks are made of is grainy, the needle of a record player will vibrate at random as it scrapes across the grain and scratch. Scratch is louder than low-volume recorded sounds, so it limits the lowest volume that can be reproduced.

Records were formerly made of a mixture of shellac and abrasive materials that hardened when pressed in heat. The records were known as shellac records. They produced much scratch. Recent records, made of vinyl plastic material, eliminate scratch and reproduce a wider dynamic range of sound.

The grooves are narrower now, allowing records that are smaller than the older kind to contain as much (in fact more) sound and allowing records of the same size as the older kind to contain much more sound. The vinyl records turn slower, too, and this is another reason they can contain more sound. The shellac records turned at 78 revolutions per minute; a shellac record 12 inches in diameter played for about 5 minutes. This standard was adapted to the spring-driven wind-up record players upon which the records were, at first intended to be played. In contrast, a 45-revolutions-per-minute vinyl record (the kind with a large center hole) plays up to eight minutes even though it is only 7 inches in diameter. A 12-inch long-playing vinyl record that turns at $33\frac{1}{3}$ revolutions per minute can play for 25 minutes.

Development of the electrical recording system has brought disk recording to an advanced state of perfection. It is wonderful to see that sounds from distinctly different sources can all be reduced to similar-appearing wiggly tracks upon a disk, and that the little wiggles can so well imitate either the roar of a cannon or the tinkling of a bell. It is even more wonderful that, through the magnetic recording method, such sounds can be recorded upon a piece of tape without so much as scratching or in any way altering the surface of the tape.

23-2. THE MAGNETIC PROCESS

The magnetic process changes the sound vibrations to electrical vibrations (an audio signal), as does the electrical disk process. It amplifies the sound signal electronically,

as does the electrical disk process. At this point the two processes differ. The disk process applies the electrical sound signal to drive a needle that cuts the disk. The magnetic process applies the electrical sound signal to an electromagnet that magnetizes the tape.

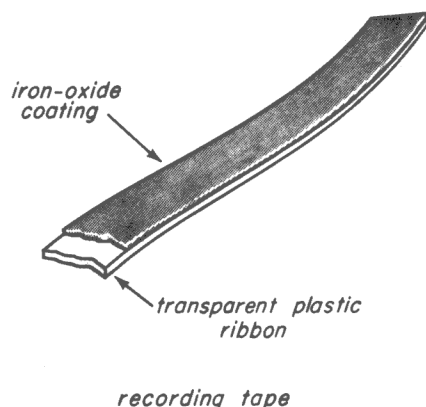


Fig. 23-4

The tape (Fig. 23-4) is of two parts. A thin transparent plastic ribbon is one part, and a coating of iron oxide is the other part. This iron oxide is a magnetic form of rust (the combination of iron with oxygen of the air), powdered and mixed with a liquid binder and spread upon the surface of the ribbon. The binder dries to a solid, flexible consistency, holding the powdered rust and binding it to the ribbon. It is the iron oxide that can be magnetized.

The width of the tape may be as great as 16 and 35 millimeters (used for movie work, it may be 1/4 inch, or it may be as narrow as 1/8 inch. Standard tape is 0.0015 inch thick. Long-playing (LP) tape is 0.0010 inch thick.

During recording, the tape is drawn across the surface of the electromagnetic pole piece. Whatever sound vibration happens to be exciting the electromagnet at a particular instant causes the tape, passing at that instant, to become magnetized to a degree that corresponds to the strength of the sound vibration. During playback, electric currents are generated in the magnet's coil, corresponding in strength to the changing degrees of magnetization of the passing tape, and hence corresponding to the strengths of vibration of the recorded sound. These currents (the audio signal) are amplified to drive

a loudspeaker; the speaker sets the air in motion. The waves of air correspond with the recorded sound.

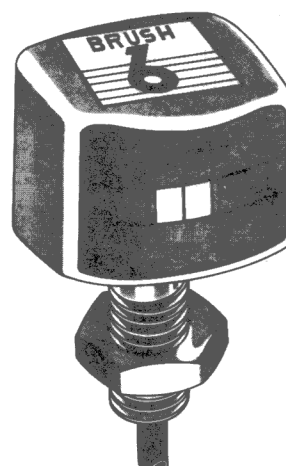


Fig. 23-5

The electromagnet (called a recording head) may be shaped like a doughnut (some are rectangular) out of which a narrow gap has been sliced. It is mounted in a head assembly (Fig. 23-5). Looking at the magnet through what would be the doughnut's hole (Fig. 23-6), you see a thin edge of tape drawn across the gap, with the iron-oxide coated flat side of the tape against the head. The gap is the pole piece of the magnet. The magnetizing coil is wound around the iron doughnut.

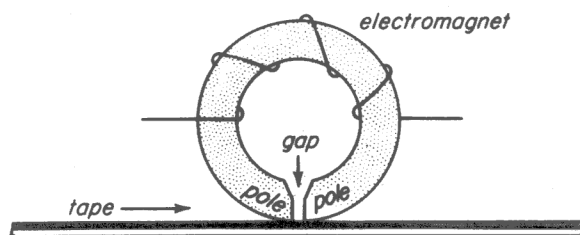


Fig. 23-6

Some of the lines of flux stretching across the gap, from pole to pole, pass through the iron coating on the tape (Fig. 23-7). Sections of the tape get magnetized as the tape slides past the gap during recording. The

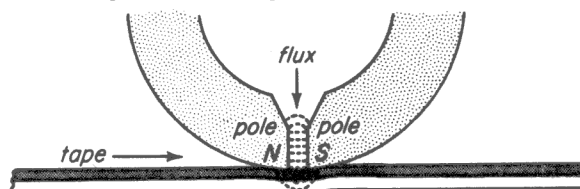


Fig. 23-7

north and south poles of the magnetized sections are in line with the direction of movement of the tape. The magnetized sections extend in a line the length of the tape. The width of tape that gets magnetized is not substantially wider than the width of the electromagnet pole piece. Pole pieces are frequently made narrow enough so that two side-by-side magnetized tracks can be placed on a tape 1/4-inch wide.

The electromagnet core is soft iron — not magnetized. For recording, a magnetic flux is set up in the electromagnet by audio currents passing through the coil. On playback, the magnetized sections of the tape induce a magnetic flux into the iron magnet as they move past the gap. The flux of varying strength that is set up in the core induces an audio-frequency current into the coil.

There is no difficulty about recording low and middle tones on magnetic tape. However, the highest audio frequency that can be recorded depends upon several factors, the most important of which are the speed at which the tape moves and the *gap length*, which is the distance between the poles of the recording head. The speed limits the highest audio frequency that can be recorded; the gap-width decides what that frequency will be. For example, the following speed-frequency relationship for some home-type tape recorders is:

7-1/2 in./sec — 50 to 8,000 cps

3-3/4 in./sec — 50 to 5,000 cps

However, with special short-gap heads, the following is obtainable:

7-1/2 in./sec — 50 to 15,000 cps

3-3/4 in./sec — 50 to 7,500 cps

In both cases, a faster speed results in a higher maximum frequency response; this is so with both the ordinary and the special short-gap head. Still, the short-gap head allows a higher maximum frequency response at a given speed; it allows response to 15,000 cps at 7-1/2 in./sec, whereas the ordinary head allows response at only 8,000 cps at 7-1/2 in./sec.

High tones are fast vibrations. One vibration, one cycle of a 10,000 cps tone, is completed in 100 microseconds. In a hundred microseconds time, a tape traveling at 3-3/4 in./sec moves a distance of 375 microinches. One recorded cycle of a 10,000 cps tone occupies 375 microinches of the tape.

Try to visualize a recording head in the process of tracing in magnetism upon a tape as the tape slides past the gap in the head. The head is excited by a 10,000 cps tone. The gap (Fig. 23-8) is a mere slit. The strength of the magnetic force acting in the slit builds up. It reaches its peak and then decreases back to the value at which it started. One cycle has been traced. One hundred microseconds time has elapsed, and 375 microinches of tape has slid past the slit. The slit traced the cycle upon the tape in magnetism. The first few microinches of the 375-microinch length of tape is magnetized lightly; the half way point is magnetized most; at the end of the tape last to pass the slit, the magnetization is again light.

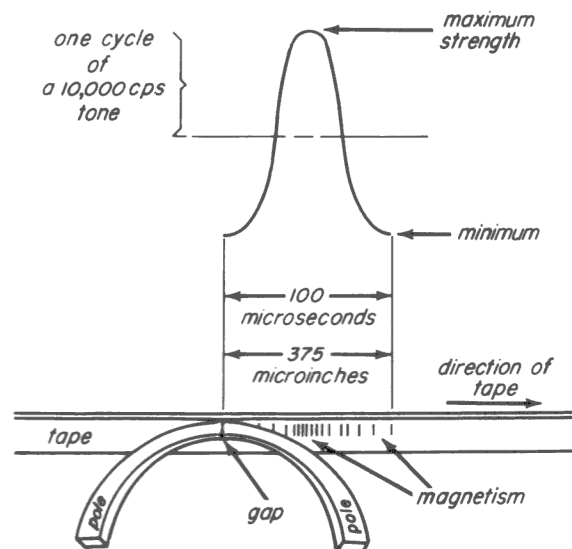


Fig. 23-8

The gap must be very short for playback. The first part of the tape to reach the slit is lightly magnetized; it sets up but little flux in the head as it passes the slit. Then, as more tape slides by, more flux builds up in the head. The rate of change of the flux density in the head closely follows the changing strength of the magnetization on

0.0001 sec
0.000375 inches

0.0005 inches

tape = 0.0010 inch

The Magnetic Process

7

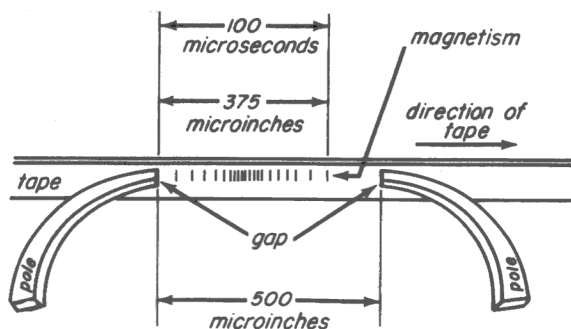


Fig. 23-9

the tape, for it is only through the short width of the slit-like gap that the head responds to the change. It is for this reason that a short gap is best.

But, unfortunately, gaps are not really so short. A good reproducer head can have a gap 500 microinches wide (Fig. 23-9). This is much longer than the 375-microinch long cycle. Such a gap can only respond to the maximum-strength part of a taped cycle of 10,000 cps tone because the part of the tape that is magnetized to maximum must fall within the gap all the time. The gap can feel no change. The tape moves 375 microinches, and the 375-microinch wide cycle moves 375 microinches. The portion of the tape on which the cycle is magnetized does not have time to pass out of the space enclosed within the gap (500 microinches). If the tape were moving faster, a taped cycle (although it would then take up more tape) would probably have time to pass the gap. And so the gap would feel changing magnetism from a fast moving tape containing a 10,000 cps tone. For this reason, fast tape speed is best where good high frequency response is desired.

There must be a gap, for otherwise the flux would stay within the doughnut-like head during recording and not magnetize the tape. Little flux would leak out of the iron doughnut to pass through the tape. So good a flux conductor is a closed circle of iron that the flux would stay within the circle, following the path of least resistance. And, during playback, the magnetization of the tape would not be strong enough to set up a flux in the iron doughnut. If great strengths of magnetism came into play during recording, perhaps a closed circle of iron could work. But then the slot has another feature — that it tends to concentrate the recording flux to

a fine line and, on playback, to respond to the tape through a fine line. With no gap, the magnetic contact between tape and head would seek its own length. It would be wider than it is with a gap. This is a matter of getting up close, of getting the tape flux path to intersect the head's flux path.

Even though a gap is employed in practical heads, and the head's flux path bulges at the gap due to the gap's greater reluctance (magnetic reluctance is like electrical resistance — see Theory Lesson 10), the tape must be kept very close to the head for good high-frequency response. Otherwise the flux paths of tape and head will not mesh. To turn the tape around so that the uncoated side touches the head and separates it from the iron side is enough to seriously worsen the high-frequency response.

Bias. A range of flux variation of the recording head close to zero strength magnetizes the tape less than a range not close to zero strength. In a large range of flux variation, the lower part of the range would not be reproduced properly. Thus, there would be a distorted record of the sound. Therefore, bias is in a range that does not approach zero.

To want to always record in strengths above zero is like wanting to live in a second floor apartment at a location that is presently a vacant lot. It is not possible unless some foundation is provided. In the magnetic recording process, the foundation is a second, helpmate magnetic flux (Fig. 23-10) induced into the head along with the signal flux. This flux is called bias. It varies in intensity at an inaudible frequency. It does not magnetize the tape. Nevertheless, its fast cycles of varying amplitude act like stilts to hold the slower cycles above the zero magnetizing force area.

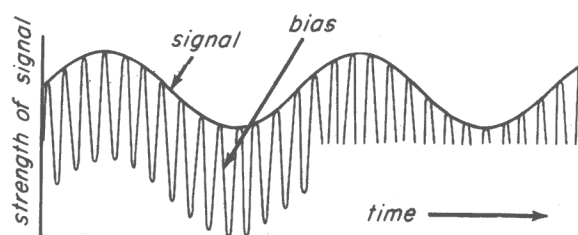


Fig. 23-10

Erase. The tape recording process has one feature that is unusual among recording processes. The record, that is, the tape, can be erased and reused again. Usually, to be erased the tape is demagnetized. For an instant, the tape is magnetized to saturation by means of a tremendously strong magnetizing flux. Then the magnetizing flux changes polarity – the north pole changes to south, the south to north – and its strength decreases; again it changes polarity, and decreases in strength, and again and again until it reaches zero. When the magnetizing flux finally reaches zero, there is no magnetization left on the tape.

Tape recorders have a separate erase head to apply the demagnetizing flux to the tape. A single head is often employed to record, bias, and play back the tape, but a separate head erases. A high-frequency alternating current electric signal is applied to the erase head; it induces an erase flux of changing polarity and varying intensity. The same signal is usually used both to induce the bias and the erase fluxes. A much stronger portion of this signal is used for erase.

The signal exciting the erase head is strong and of constant strength. However, because the tape slides past the head, the strength of erase flux that is applied to any one section of tape decreases and soon reaches zero strength as the section of tape moves away from the head. Thus, each section of tape is subjected to an alternating flux that is at first strong, then gradually decreases to zero.

Tape can also be erased by a d-c process, by a process in which direct current is applied to the erase head. A head excited by d.c. produces a magnetic field of constant strength and one polarity; it does not alternate in polarity or vary in strength. Therefore, it cannot demagnetize a tape. However, tape does not necessarily have to be demagnetized to be erased. It is the *variations* in magnetism that must be removed from the tape to erase it clean of sound. This can be done by magnetizing the tape to a strong but constant degree, and a d-c field can accomplish this. The disadvantage of it is that, when saturated in magnetism, the tape is noisy. Therefore, the a-c erase process is

most commonly employed. However, there are advantages to the employment of permanent magnets for erasing tape; these magnets produce a constant field like that of a d-c electromagnet.

Imagine the tape to be passing a row of permanent magnets each of constant strength, each having opposite polarity to that of its neighbor, and each weaker than its neighbor – with the strongest one positioned to meet the tape first. Passing such a row of magnets, the tape would be subjected to a field of gradually decreasing strength and changing polarity. It would be erased and demagnetized just as when subjected to the alternating and gradually decreasing field of an a-c erase head.

Of course, the row of magnets would make an expensive and excessively large head. But the underlying idea is used in the design of a practical PM (permanent magnet) erase head that demagnetizes. The PM head shown in Fig. 23-11 has an irregularly shaped diagonal gap. The gap gives forth a field of uneven strength and changing polarity – strong at the left-hand side and decreasing to the right. The field is concentrated to a small enough area so that half the tape can be erased without affecting the other half; thus the head is usable with dual track tape recorders. It is small and its cost is reasonable.

23-3. TAPE RECORDERS

A schematic of a typical tape recorder is shown in Fig. 23-12.

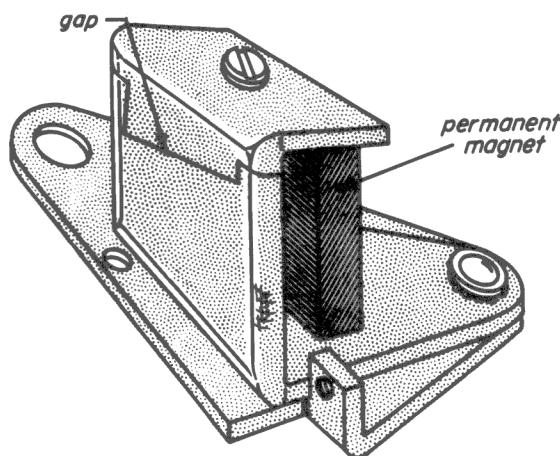
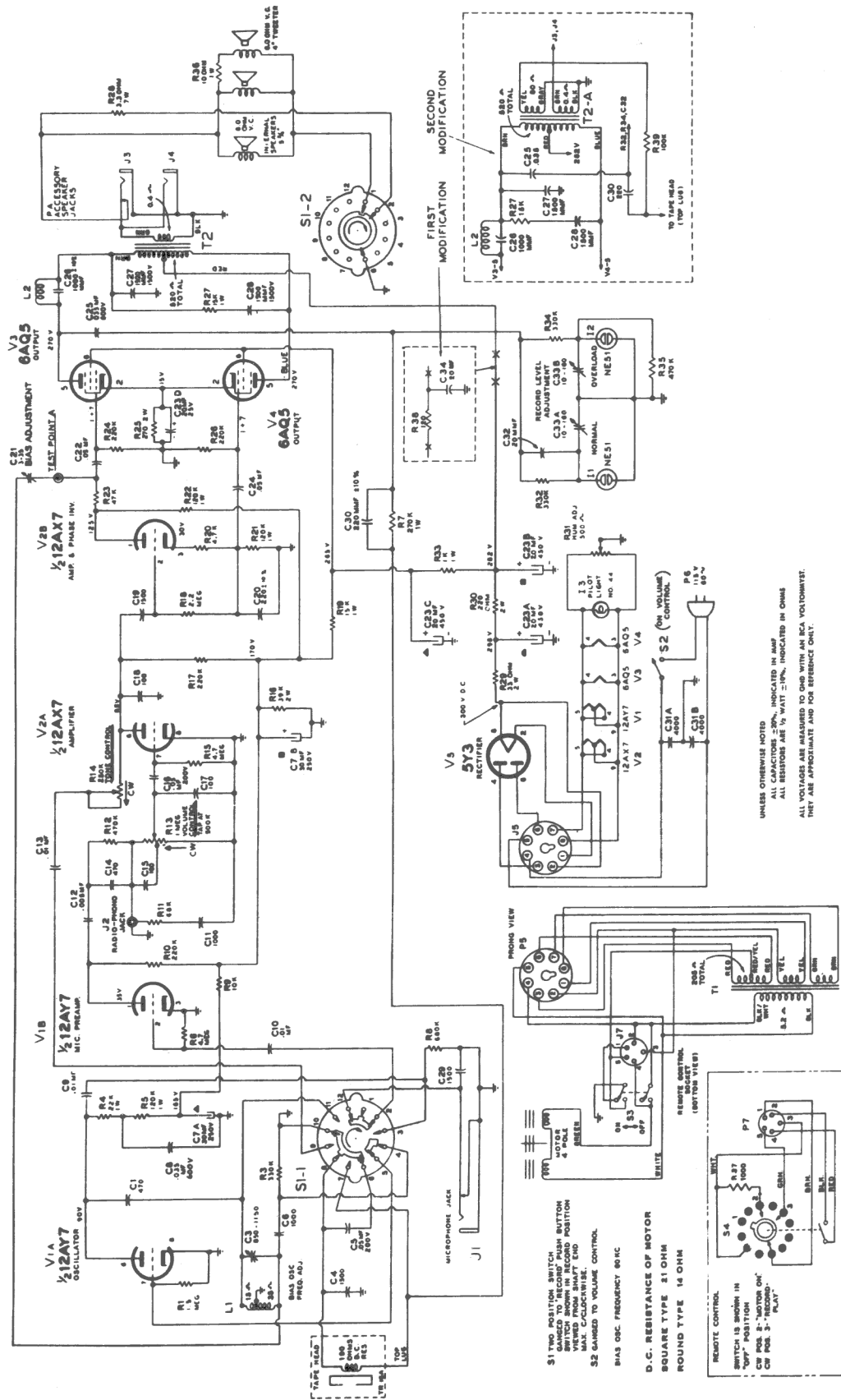


Fig. 23-11



schematic of a typical tape recorder

Fig. 23-12

The workings of all the parts of a tape recording machine center around its magnetic heads. The sound to be recorded is picked up, amplified, and processed in the electronic part of the machine and eventually delivered to the recording head. The bias-erase signal is generated in the electronic part of the machine and divided in two. A portion is delivered to the recording head for bias and the other portion is delivered to the erase head. The tape delivers its signal to the playback head where the sound to be played back first enters the electronic part of the machine. Even the mechanical part of the machine has for its main function the task of transporting tape past the magnetic heads.

Home-type tape recorders usually have two heads — one to record, play back, and bias; the other to erase. These are mounted close together, side by side, and the tape is caused to slide past the poles of both of them. The tape reaches the erase head first. During recording, both heads are excited. Tape is erased clean of all sound-producing magnetism as it passes the first head. It arrives unmagnetized at the second head, ready to be recorded anew. In order to erase without recording, the tape is run through with the machine set to record without a microphone connected to the machine.

On playback, the erase head is not excited; therefore, tape slides past it without getting erased and the play-record head is not excited; instead, it stands ready to generate a signal in correspondence with the passing cycles of magnetism on the tape.

The Electronic Circuits. From knowing the functions of the magnetic heads, it is possible to figure out the function of the electronic circuits (Fig. 23-13) that are associated with them.

The input of a tape recorder must be ready to take in electrical sound signals from a microphone, a record player, a radio, or even another tape recorder. The microphone delivers a faint signal, so an additional stage of amplification is needed to

raise it to approximately the same strength as the signals that are less faint are fed directly to the phono input jack, (Fig. 23-13) input signals.

The same amplifier chain used to carry the input signal to the recording head when the machine records (Fig. 23-13a) is used to carry the signal from the playback head to the loudspeaker when the machine reproduces (Fig. 23-13b). The front-panel operating con-

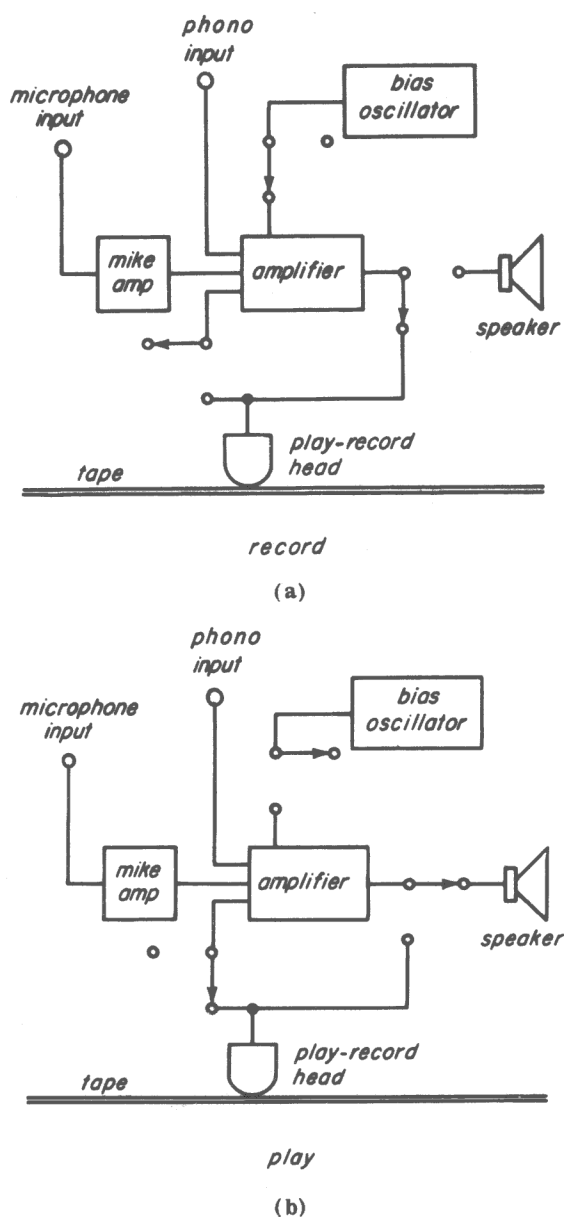


Fig. 23-13

trols of the recorder electrically switch the amplifier chain from the record condition to reproduce condition. This arrangement, cheaper than two separate amplifiers, is

usually employed in home-type recorders. Although a recording cannot be monitored off the tape (through a playback head) while being recorded on a home-type recorder, such a recorder usually has a single combined play-record head; off-the-tape monitoring is impossible with such heads, anyway.

A dual-purpose play-record amplifier is wired like any other audio amplifier, especially in the playback-switch position, wherein the power-output stage drives the speaker and is wired to be identical with radio-type power output stages.

In the record position, the power-output stage drives the record head. Generally, the record head does not require as much power as a speaker. Were it not that dual-purpose amplifiers must be capable of driving the speaker, the output stage could be a simpler one, capable of delivering less power. As things stand, the designer has no difficulty coupling the low-power record head to the high-power output stage. It is as if the stage were designed to operate a speaker with the record head clipped on for good measure.

Bias signal must reach the record head, and some designs have it pass through the output stage to get there. Thus, the output stage may have additional components needed to process bias signal. This kind of tape-recorder output stage carries two separate signals — the sound signal and the bias signal — for, rather than being combined, these signals are merely mixed together. The sound signal originates at the input to the machine; the bias signal is generated in an oscillator stage within the machine. They remain independent of each other.

Passing oscillator signal through the output stage is a way designers have of increasing the strength of the bias signal without using an additional amplifier for that purpose. In this way, the oscillator need not deliver a strong signal. Oscillators not required to deliver a strong signal are less inclined to frequency drift; simple oscillator circuits can be employed.

Another way is to use a high-power oscillator. The output of the oscillator is applied directly to the record and erase heads rather than to the input of the power amplifier (Fig. 23-14).

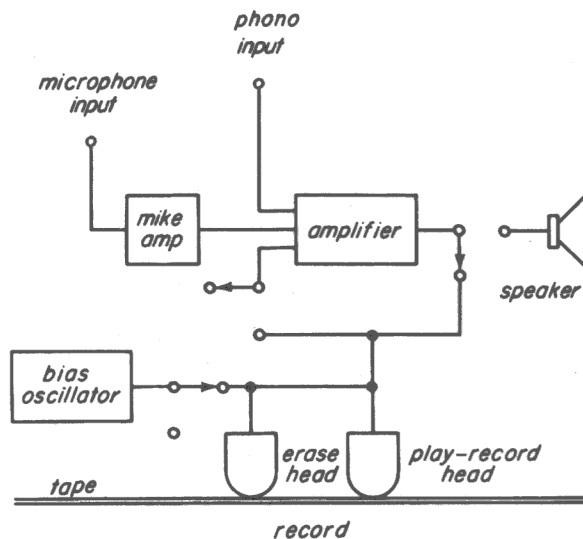


Fig. 23-14

There is still another way. The sound signal and the bias signal are so distinct and separate that the power output stage can be designed to oscillate as a power oscillator at the bias frequency while at the same time it amplifies at the signal frequency.

In any case, the sound and bias signals in a tape recorder are sometimes separated, sometimes combined. A serviceman, in order to circuit-trace tape recorders, should learn how to recognize where these signals separate and where they combine. Remember that bias signals pass easily through a capacitor of about $1,500 \mu\text{f}$ or less; sound signals do not pass. For example, the circuit diagram of Fig. 23-15 shows that the combined sound and bias signals are applied through a $0.035 \mu\text{f}$ capacitor to a neon level-indicator bulb;

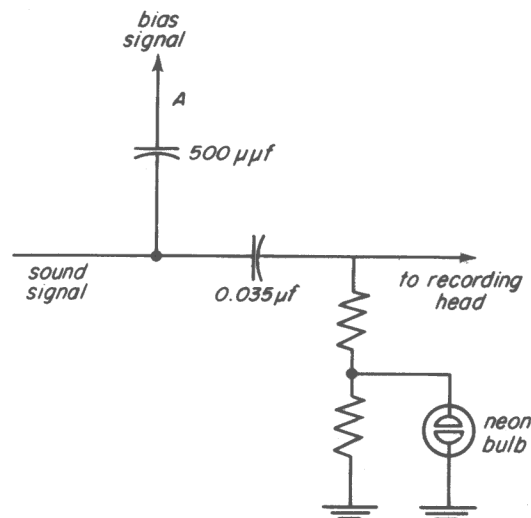


Fig. 23-15

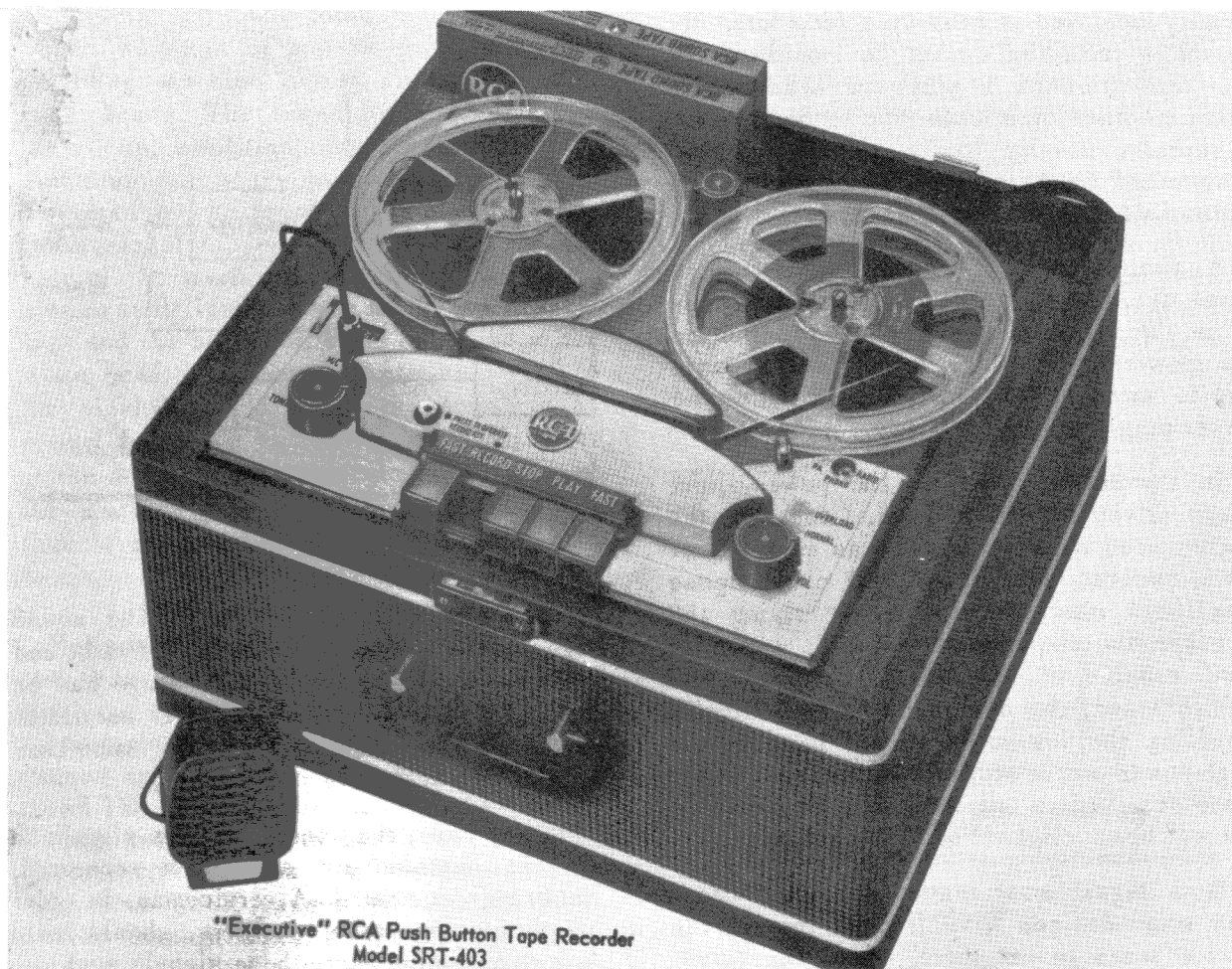


Fig. 23-16

but at point A in the circuit, the bias signal stands alone — separated from the sound signal by a 500- μmf capacitor.

Signal-level indicators show when the recording signal is so strong that it will overload the tape if the operator of the recorder does not reduce it. Neon bulbs, Magic Eye[®] tubes, and meter movements commonly serve as the indicators. One or the other of these is to be found upon the front panel of all tape recorders. When the recording signal is too high, a volume control serves to reduce it. Often, this same control serves to regulate volume during playback.

The Mechanism. On the front panel of the tape recorder in Fig. 23-16 you see two reels. One holds the supply of tape to be recorded or played; the other takes up tape after it has moved from the supply reel past the heads. Tape moves in the same direction to play as to record.

The tape is not pulled past the heads by the take-up reel (Fig. 23-17). The take up reel simply accumulates tape, and the supply reel discharges tape. The tape is pulled from the supply reel and past the heads by the *capstan*. The capstan is a little wheel located so that the tape passes against it just before reaching the take-up reel. The capstan is turned by a motor. The tape is

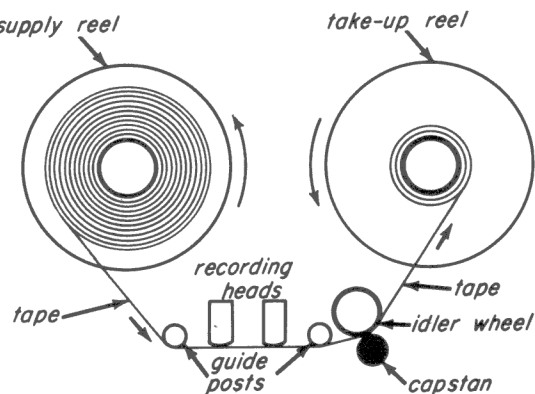


Fig. 23-17

squeezed firmly against the capstan by an idler wheel. The idler is free to turn on its axle and turns because the motor-driven capstan engages it. The take up reel is motor driven, but it can pull the tape no faster than the speed of the capstan allows; the tape is too firmly clamped between capstan and idler to be pulled any faster than the capstan feed it through.

The take-up reel turns at an unconstant speed (Fig. 23-18). This is necessary because the circle of tape on the take up reel enlarges with each turn. The reel turns rapidly to wind the first loops of tape at the hub (a). Then the loops of tape pile out from the hub and a longer piece of tape is accumulated with each new turn of the reel (b). It takes longer to accumulate the longer loops of tape, so the reel turns slower — and slower.

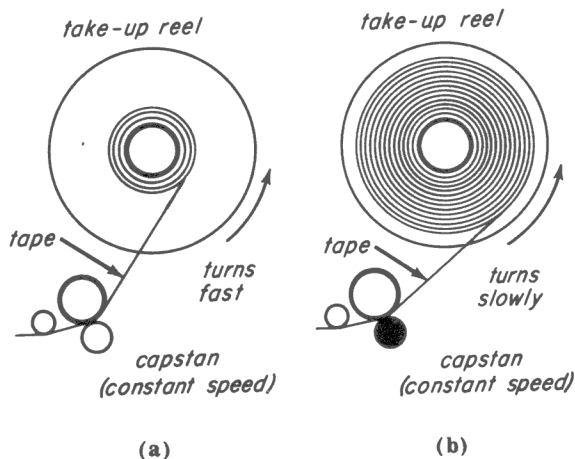


Fig. 23-18

Although the speed of the motor drives the take up reel is constant, the reel and motor are connected in a way to permit slippage when the tape resists being pulled as fast as the reel is going. It is the tape (held back by the capstan) that slows the take-up reel. With no tape in place, the reel spins rapidly at a constant speed. The tape can withstand the light pull of the reel without breaking. The pull of the reel is so light that if you stop the tape completely by grasping it in your hand (Fig. 23-19a), it will not be broken. Instead the reel will stop turning while the motor continues and the coupling between reel and motor slips.

The only place where the tape is firmly gripped is at the capstan. The capstan drive

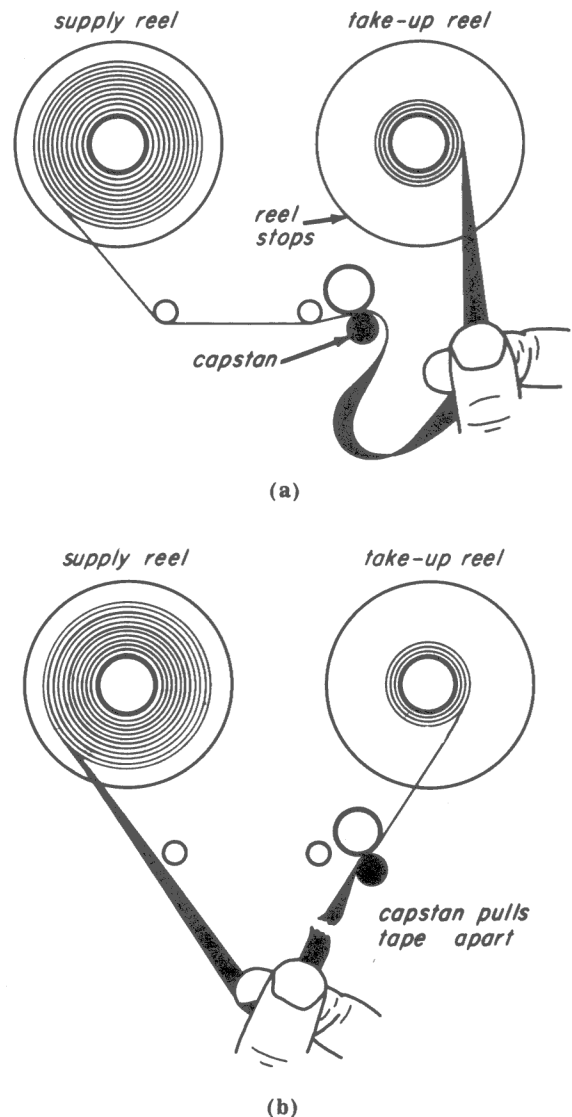


Fig. 23-19

does not slip. If you hold and stop the tape before it reaches the capstan, it will break; the capstan will pull it apart. See Fig. 23-19b. (It takes about five pounds of pull to break a tape.)

The supply reel resists the pull of the capstan. The tape withstands the light pull, overcomes the resistance of the supply reel, and is pulled by the capstan. While there is much on the supply reel, it turns slowly in response to the pull of the tape that is unwinding. As the roll of tape diminishes, the reel turns faster. The supply reel turns

faster as the take-up reel turns slower (Fig. 23-20). All the while, the tape moves at a constant speed — pulled past the heads by the capstan.

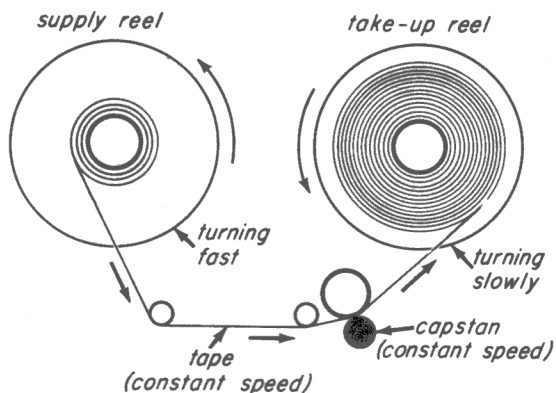


Fig. 23-20

A device such as the capstan is needed to pull the tape past the heads. If the take up reel were used for this purpose, it would have to be driven at an ever decreasing speed in order to pull the tape at a constant speed. The capstan makes this unnecessary.

Tape moves in the same direction for both recording and playback. If the tape has been run off for recording, it must be rewound before it can be played. If it has been run off for playback, it must be rewound before it can be played again or re-recorded. The capstan does not pull the tape on the rewind; a constant tape speed is not necessary when the tape is rewinding. On rewind, the tape is pulled backward by the motor driven supply reel (Fig. 23-21a). The capstan's grip on the tape is released, leaving only the take-up reel to oppose the backward pull of the supply reel. At the same time motor coupling to the take up reel is slackened; that to the supply reel is tightened; and the speed of the supply reel is increased. The tape rewinds rapidly.

Most home-type machines have two forward operating speeds — 7-1/2 in./sec and 3 3/4 in./sec. In addition, they have a fast rewind and a fast forward speed. The fast forward speed is used to quickly arrive at a desired section of tape that is located deep in the roll. Were it not for the fast forward speed, a person wanting to hear a section of tape located half way through a seven-inch reel recorded at 3-3/4 in./sec would have to listen to thirty minutes of unwanted sound before the desired sound commenced. For

fast forward operation, (Fig. 23-21b) the tape is released from the capstan's grip, and is pulled by the rapidly turning take-up reel, while the supply reel maintains a light opposition that steadies the tape.

The controls that govern the mechanical operation of tape recorders have a neutral position in which the tape does not move at all — the capstan's grip is released from the tape, no turning power is applied to the supply and take up reels, but the motor and capstan continue to turn. Also, tape recorders are equipped with brakes — similar to automobile brakes — to halt the tape whenever necessary.

Some machines are designed to record two sound tracks on a 1/4-inch tape; others are designed to record a single sound track on 1/4-inch tape. The two types of machines have different types record — playback heads. The mechanical functions of dual-track and single-track recorders are identical. The dual-track head records a narrower track than does the single-track head and the nar-

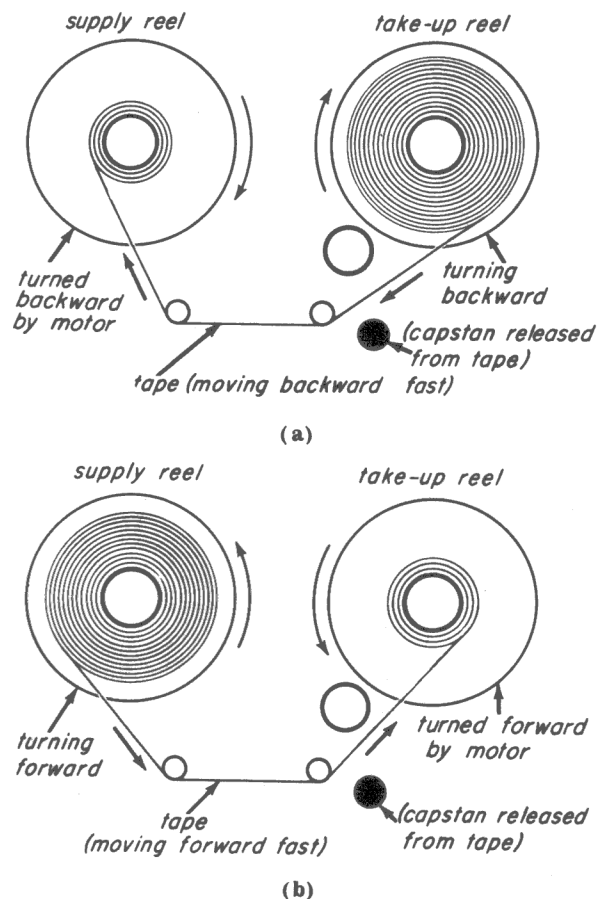


Fig. 23-21

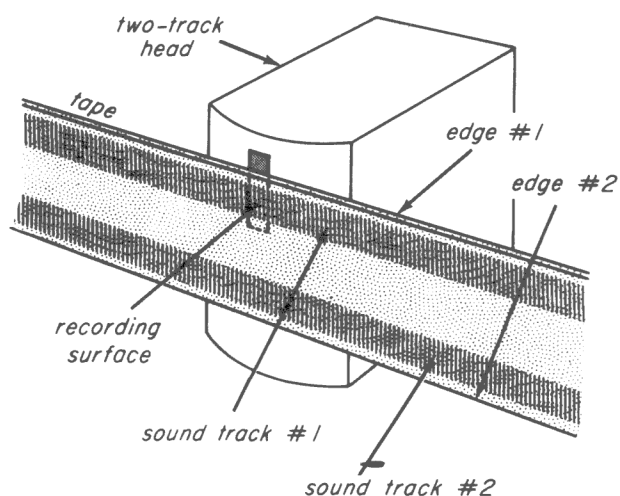


Fig. 23-22

row track is positioned near the edge of the tape (Fig. 23-22). After one track of sound has been recorded at one edge of the tape, the tape is turned so that the other edge comes into contact with the recording surface of the head, and a second track of sound is recorded on the second edge of the tape. The procedure is as follows:

1. Place a full reel of tape on the supply reel spindle.
2. Run this tape past the heads and record upon it until all tape is accumulated upon the take up reel.
3. Switch reels. Place the now full take-up reel in the supply-reel position and place the now empty supply reel in the take-up reel position.
4. Thread tape from the full reel past the heads and record the second track.

When the reels are switched, it is necessary to turn the full reel over in order to have the tape unwind in the correct direction of reel rotation. Turning the reel over turns the unrecorded edge of tape over, placing it in position to contact the recording surface of the head. Thus the tape is automatically positioned to receive the second sound track. The procedure is the same for playback, except that you set the recorder to play rather than to record. Note that it is not necessary to rewind the tape when going from the end of one sound track to the beginning of the next.

23-4. A TYPICAL TAPE-RECORDER MECHANISM

Let us devise a mechanism to perform the mechanical functions of a home-type recorder. Let us do so, step by step — taking one function at a time. Our purpose is to gain an understanding of how component parts contribute to the over-all performance of a typical machine — information a serviceman needs to help him analyze tape recorder machinery. Machinery of varying design can be employed to perform the mechanical functions of a recorder. Our example is typical; it does not represent the *only* way.

We start with a motor (Fig. 23-23). Most home-type machines have only one motor. Professional machines usually have more than 1 — for example, one motor to drive the capstan and another to drive the reels. The example employs but one motor.

The first thing we connect to our motor is the capstan. The speed of the capstan must be quite constant. If it is not, the recorded sound will *wow* — that is, the pitch will go up and down as the speed of the capstan (and therefore that of the tape) increases and decreases.

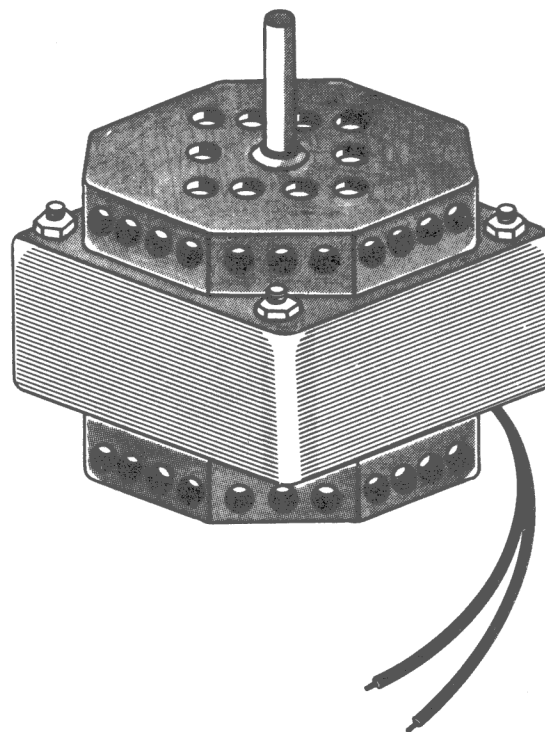


Fig. 23-23

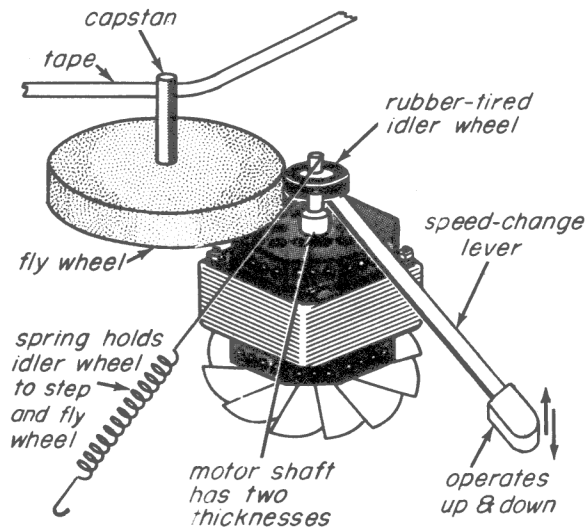


Fig. 23-24

To make sure that the speed will be constant, we take two main precautions. We choose a motor large enough to easily carry the load to be placed upon it so as to prevent momentary changes in the amount of load from affecting the speed of the motor. We choose a motor somewhat larger than a phonograph motor. Also, we attach a fly wheel to the capstan. This is a relatively heavy wheel of relatively large diameter. Once you get the flywheel going at a certain speed, it resists any change of speed. The capstan shaft connects to the center of the fly wheel (Fig. 23-24).

We mount the motor with its shaft near the rim of the fly wheel. Then we mount a rubber-tired idler wheel so that it is held (by the force of a coil spring) against both the shaft of the motor and the rim of the fly wheel. The

motor shaft turns the idler: the idler turns the fly wheel; and the capstan turns with the fly wheel. With this drive arrangement the cushioning effect of the idler wheel's rubber tire and the pressure spring absorbs unwanted sideways motor vibration before it reaches the capstan where it can jiggle the capstan shaft and cause it to rattle noisily in its bearing.

The diameters of the motor shaft, the idler wheel, the fly wheel, and the capstan all combine to determine the speed at which the tape is moved. A change in any of these dimensions changes tape speed. Therefore, to provide for two tape speeds (7-1/2 in./sec and 3-3/4 in./sec), we can arrange to have two thicknesses, in steps, at the end of the motor shaft. Pressing the rubber-tired idler to the narrow part of the shaft chooses the faster speed. We provide a lever to move the idler between the wide and narrow section of shaft. We call this a *speed-changing lever* — one of the front-panel operating controls.

Of course, we locate the capstan with its pressure roller in position to draw tape across the heads. With the machine in record operation, we want the tape to be drawn across both heads. In play operation, we want the tape to be drawn across only the play-record head. Here we encounter a need for two more operating controls — a *record control* and a *playback control*. So we mount the playback control lever (Fig. 23-25). This lever acts to pull the play record head to the tape. (It does not move the erase head from its neutral (away from the tape) position.

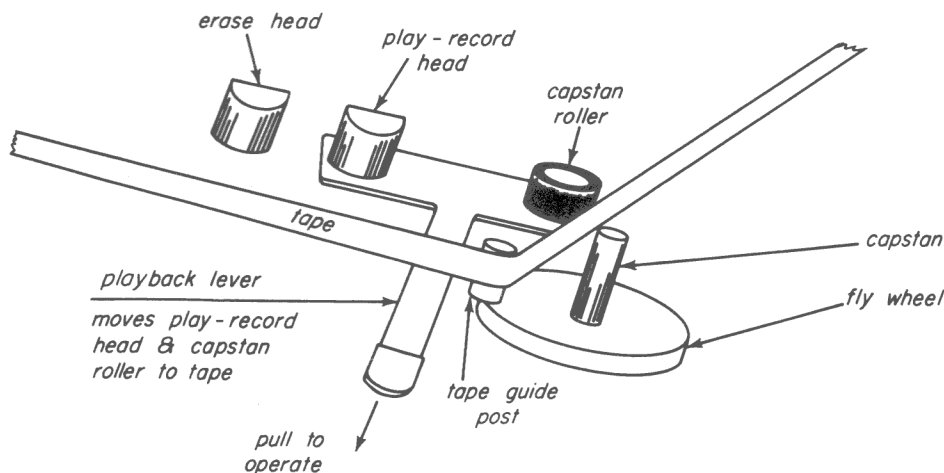


Fig. 23-25

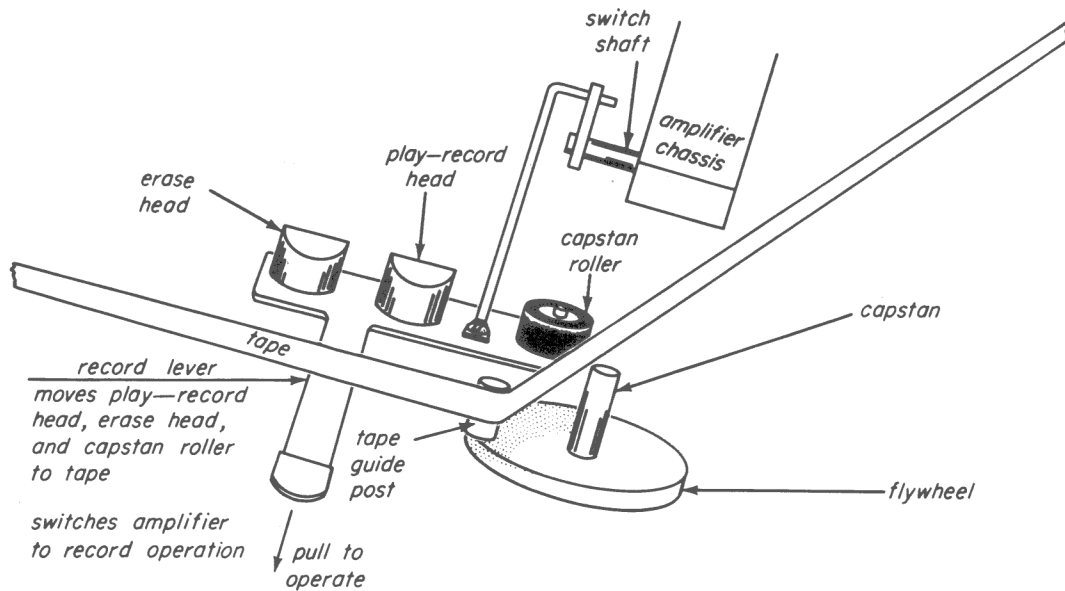


Fig. 23-26

A playback control must start the tape in motion, as well as engage it with the head. To accomplish this, the tape must be pressed to the turning capstan; the capstan roller must be moved against the capstan shaft where it can squeeze the tape to the capstan. Our playback lever does two things: It moves the play-record head to the tape, and it moves the capstan roller to the capstan.

We can devise a similar lever to place the machine in record operation (Fig. 23-26). It must do four things. Like the playback lever, it moves the play-record head to the tape, and it moves the capstan roller to the capstan. In addition, it moves the erase head to the tape, and it switches the amplifier from playback to record operation.

Now, our machine can work. At least it can record, play back, and erase at two speeds, and we have outfitted it with levers to control these functions. As yet, we have not provided means to reel off and wind in the tape. To provide for reeling off the tape, we mount a spindle on which to place the supply reel. The capstan will pull the tape from the reel. To provide for winding the tape on the take-up reel, we need a spindle with turning power applied to it; the coupling must slip when the tape resists winding; and we want turning power at the take up spindle only when the control levers are in the record or play positions, not in the off (neutral) posi-

tion. One kind of coupling that provides slippage is a long coil spring, the ends of which are joined to make a drive belt stretched between two pulleys (Fig. 23-27). When the motor-driven pulley is pulled away from the other pulley, coupling between them will tighten; the second pulley will turn, and it will be able to slip in the grip of the spring belt. The second pulley can be attached to the take up spindle. The motor driven pulley can be pulled (to tighten coupling) by the play and record control levers.

The pulley to be motor driven can be coupled to the motor shaft. However, there is

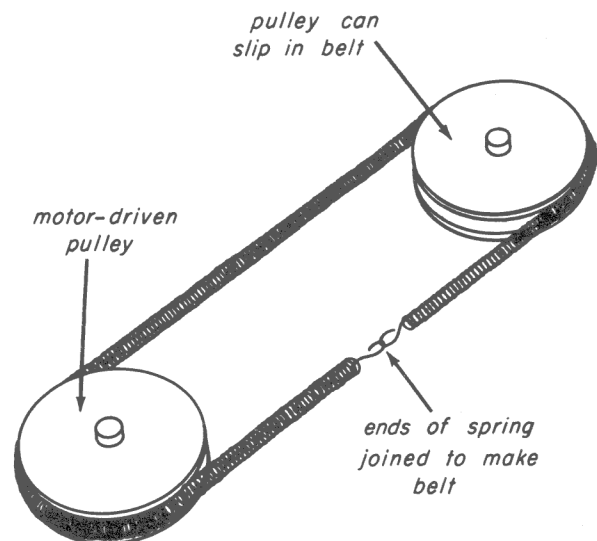


Fig. 23-27

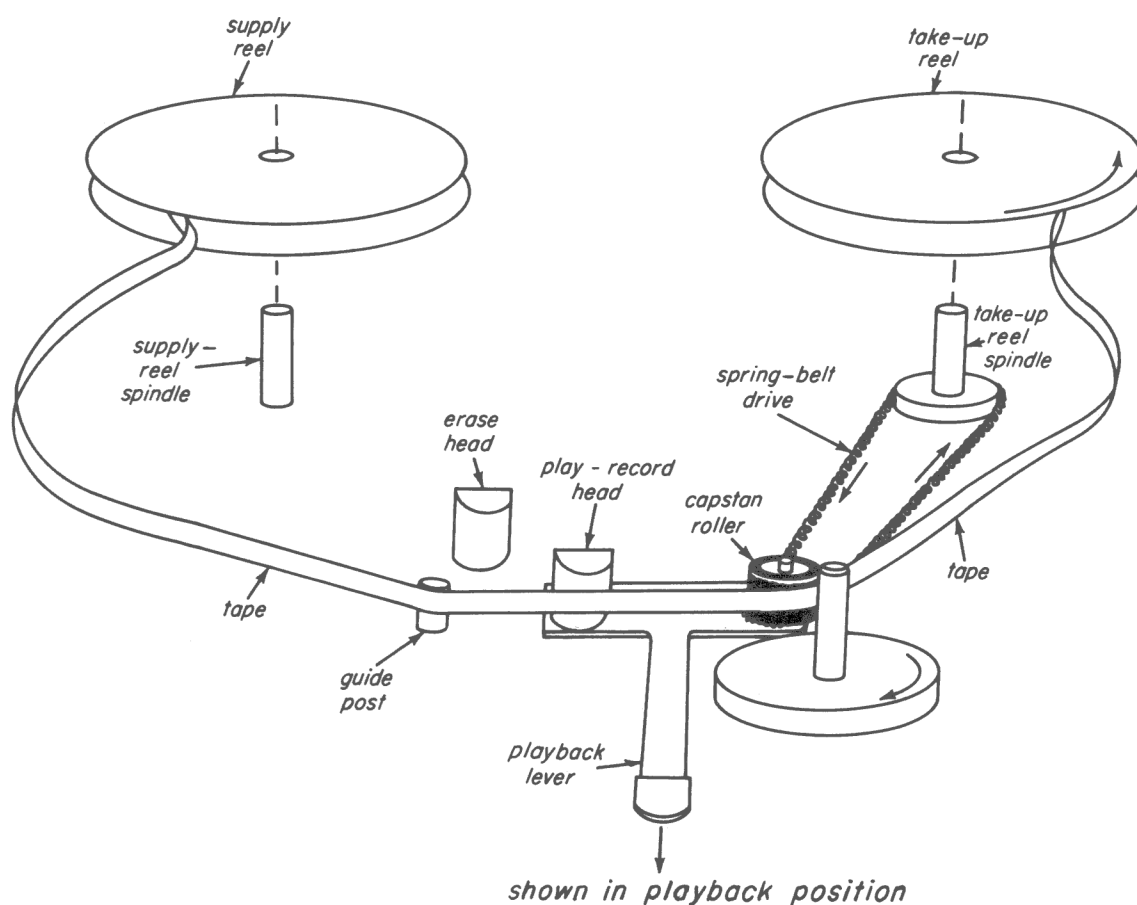


Fig. 23-28

an easier way to give it turning power at just the right control setting. The capstan roller is already attached to the play-record levers; it turns, it is motor driven only when the levers are in the play or record positions (not in the neutral positions). If we fasten the pulley that is to be motor driven to the capstan roller (Fig. 23-28) we will have what we want. The take-up spindle will be motor driven through a slipping coupler in the play or record lever positions.

Although the supply reel does not have to be motor driven in forward operation, it does have to be braked. Otherwise it will spill tape when the control levers are moved to the neutral position to stop a recording or playback that has been in progress. It will spill tape because the take up reel, loaded down with a power-coupling device, tends to stop before the supply reel. The supply reel tends to continue to turn and discharge tape, but there is nothing to take up this tape with the take-up reel stopped.

The take-up reel requires brakes, too. During rewind, the take-up reel acts like the supply reel does in forward operation. During rewind, the take-up reel turns to discharge tape, and if it does not stop with the supply reel (which is collecting tape), the tape will spill. In fact, it is best to have brake action applied to both reels at the same time. If only the discharging reel is braked, the other must jerk to a stop against the tape (which is wound around both reels). The sudden force of the stop can break the tape. It can also jerk the collecting reel backward and start it turning backward — discharging tape.

We want our mechanism to brake both reels at the same time. We want to be able to apply the brakes in all modes of operation — forward and reverse — play and record. We want to be able to release the brakes in the neutral mode of operation, so that the tape can be freely moved by hand for threading purposes.

To brake the spinning reel spindles we can devise a pair of spring loaded pads to press against the spindles. But it is not satisfactory to press the pads directly to the spindles. A thin spindle cannot be stopped in this way unless great pressure is applied. Little braking pressure is required at the rim of the reels, but reel rim brakes would be awkward. We can get around all this by mounting a wheel, the size of a small reel of tape, on the underside of each spindle. The brake pads will press against the rims. The wheels have wide rims to accommodate the brake pads. We call these wheels *brake drums* (Fig. 23-29).

The two brake pads are mounted on each end of a single strip of spring metal and are operated by a lever connected to the strip at its center, half way between the pads. This lever is another front-panel control — *the stop lever*. The stop lever moves the capstan roller away from the capstan as it moves the brake pads against the drums. Thus, in play or record operation, the tape is released from the capstan when the brakes are applied to the reels.

All that remains to complete our mechanism is a fast forward and a reverse-drive system. The take-up reel has to be driven

counterclockwise for fast forward operation and the supply reel has to be driven clockwise for reverse operation. To accomplish this, we mount two rubber tired wheels on a long sideways moving lever (Fig. 23-30). The other end of the lever is a front-panel handle. The lever is pivoted at its center. Moving the handle to the left brings the right hand wheel into contact with the take-up reel brake drum. Moving the handle to the right brings the left-hand wheel into contact with the supply-reel brake drum. The rubber-tired wheels are motor driven in opposite directions through belts and pulleys. The drive belt of the left-hand wheel is twisted one half turn to reverse the direction of rotation. Our typical tape recorder mechanism is complete.

23-5. SERVICING TAPE RECORDERS

Troubleshooting a tape recorder mechanism is largely a matter of knowing the functions of the component parts and of checking parts associated with whatever function the machine fails to perform. For example, if our typical machine fails to rewind, we check the coil spring drive belt that couples power to the supply reel during rewind. The spring belt might be broken.

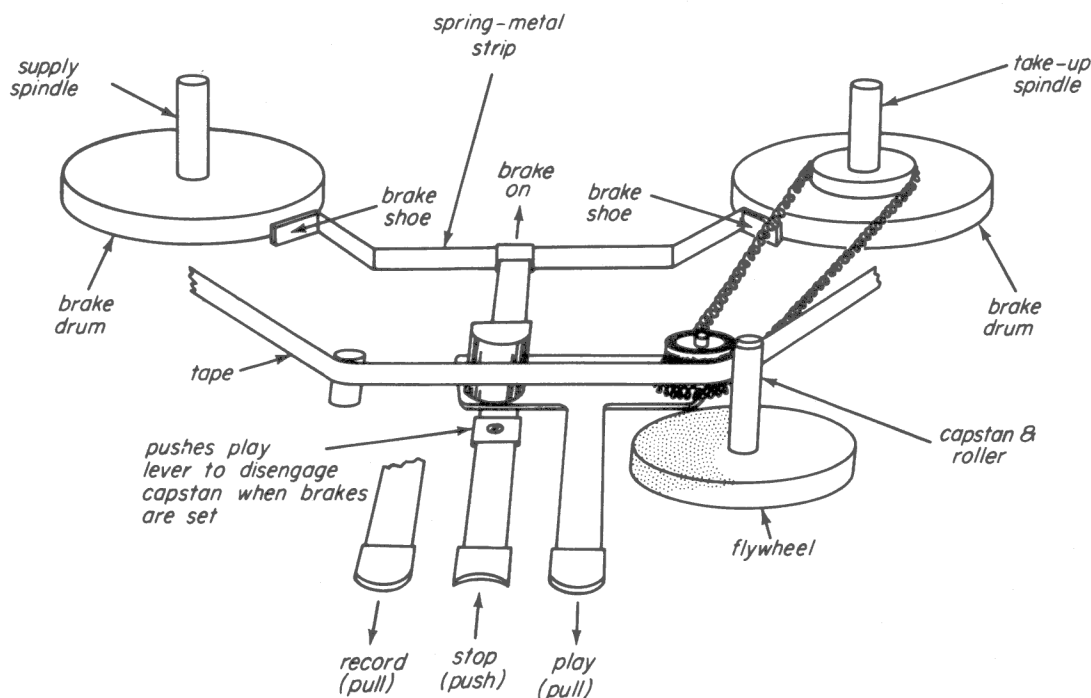


Fig. 23-29

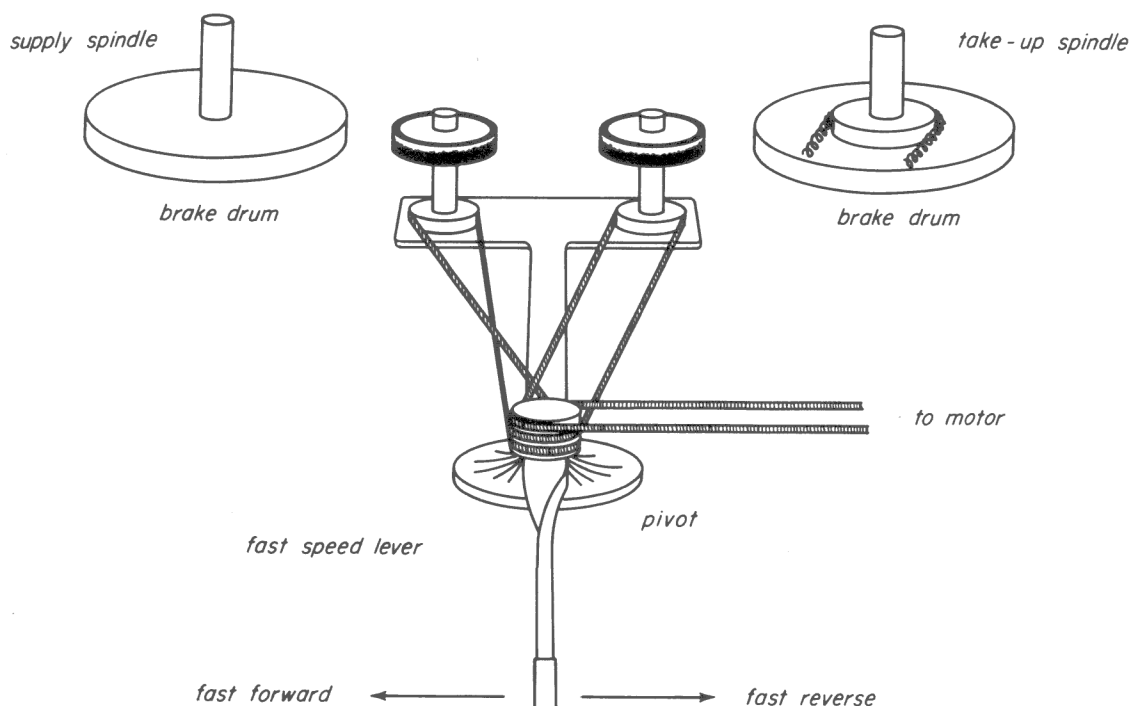


Fig. 23-30

However, troubles such as wow, flutter, or slow tape speed do not represent failure to perform functions (like the fast forward function). Such troubles cannot be directly related to defective component parts. Wow and flutter result from irregular tape speed — wow from slowly changing speed and flutter from rapidly changing speed. Most likely, the capstan speed is irregular, although it is possible to have wow and flutter while the capstan speed remains regular. The capstan roller might not be pressing the tape to the capstan with enough force, or an obstruction to the free turning of the supply reel might be causing a jerky resistance to the pull of the capstan, etc.

Where the speed of the capstan is irregular, a flat-tired drive wheel is frequently at fault. Drive wheel tires develop a flat when the mechanism jams so that the wheel cannot turn. Then, the motor shaft, which normally turns the wheel by rotating against its edge, spins against one spot on the soft rubber tire of the stationary wheel, and this one spot flattens out.

Slow but constant tape speed does not seriously detract from the quality of the recorded sound as long as the recording is played back on the same slow machine upon

which it was recorded. It is when you record on one machine and play back on another that slow tape speed spoils the sound. Even then, there is no spoilage if both machines operate at the *same* slow speed. Slow but constant tape speed is usually caused by a defective motor or excessive tightness in the coupling of the motor to the capstan or the reels.

Speed can be checked with speed timing tapes and with the stroboscope. The speed-test tapes have beeps recorded at accurately spaced distances along the tape. When the tape is played at the standard speeds, the beeps should occur at certain time intervals. If the beeps actually occur at longer intervals, the machine is slow. The timing of the beeps may be checked against a wrist watch or an electric clock. For example, a speed-test tape might be recorded to beep every 5 minutes when played at 7-1/2 in./sec. If it actually beeps every 6 minutes, the machine upon which it is being played must be slow.

Use of the stroboscope for testing phonograph turntable speed was explained in Service Practices 22. The stroboscopes used to test tape recorders work on the same principle, but they look different and are smaller (Fig. 23-31).

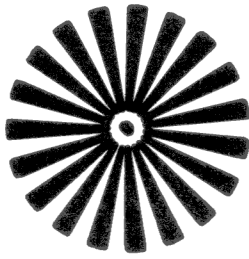


Fig. 23-31

They must fit on the capstan. It is the speed of the capstan that is tested by stroboscope, not the speed of the tape, itself. Capstans turn at nonstandard speeds. Different recorder designs obtain the same standard tape speeds with capstans of various diameters turning at various speeds. For this reason, a standard stroboscope pattern will test all machines cannot be had. Some manufacturers print a stroboscope pattern in their service notes that may be used to test their machines.

In use, the stroboscopic disk is attached to the end of the capstan shaft so that it rotates with the capstan while the machine operates. The spoke-like pattern of the revolving disk is observed under a 60 cps fluorescent light. At the correct speed, the spokes seem to stand still. When the machine is slow, they appear to rotate slowly in a direction opposite to the direction of rotation of the capstan. When the machine is fast the spokes appear to rotate slowly in the direction of the capstan's turning.

Momentary speed variations can be detected with the stroboscope; it is useful for detecting wow and flutter troubles. Timing beeps on tape are not useful for detecting wow and flutter, but a constant tone recorded on tape can be used for this purpose.

In addition to the location and correction of defects, tape-recorder servicing involves adjustments to the mechanism. The adjustments required vary from one design to another, as do specific details of adjustment procedure. Manufacturers service notes should be consulted for the correct procedure to be followed with whatever machine you are servicing. However, some typical adjustments and the reasoning behind them can be considered without reference to any specific recorder design.

One adjustment that tape recorders require is positioning of the play-record head. The head must be positioned so that the gap is flush with the passing tape. If it is not, insufficient sound output from the machine results. Also, the head must be positioned so that the slit of the gap is absolutely vertical (at right angles to the edge of the passing tape). If it is not, poor high-frequency response results. The tape *sees* a wider gap if it passes the slit at a slant angle than if it passes the slit at a straight angle. Of course, a wide gap reproduces high frequencies poorly.

It is best not to position the head by eye but rather to adjust the position of the head by making use of instruments. A test tape, recorded with a constant high frequency tone, and an output meter are needed. The output meter is connected to the amplifier in a way to read the output signal strength. It might, for example, be plugged into the recorder's external loudspeaker jack. Alternatively, it might be clipped across the voice coil terminals of the internal speaker. To set the gap flush with tape, the face of the head is moved back and forth in a sideways arc against the passing test tape until the meter reading is maximum (Fig. 23-32). This adjusts the head for maximum output at all frequencies. The test tape used to accomplish the adjustment may be recorded with a tone of any frequency as long as the amplitude of the tone is constant.

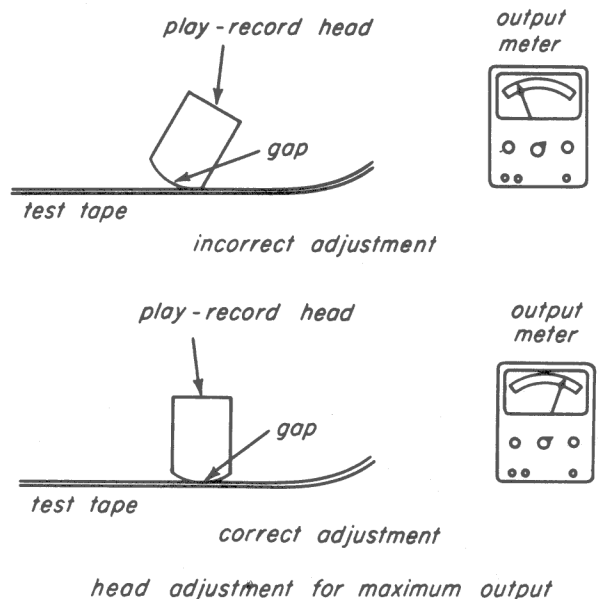


Fig. 23-32

To adjust for maximum high-frequency response, the test tape must contain a high frequency as well as a constant amplitude tone. Any frequency near the upper frequency-response limit of the recorder under test is satisfactory. For example, if the recorder is capable of response to 8,000 cps, a 7,000 cps constant tone is satisfactory. The test tape may be prepared by recording such a tone from a signal generator, or a manufactured head-alignment test may be purchased.

When adjusting for maximum high-frequency response, the output meter remains connected as before; the high frequency test tape is set in motion past the head; and the head is tilted from side to side until the meter indicates maximum. At this position of the head, the slit is vertical (Fig. 23-33).

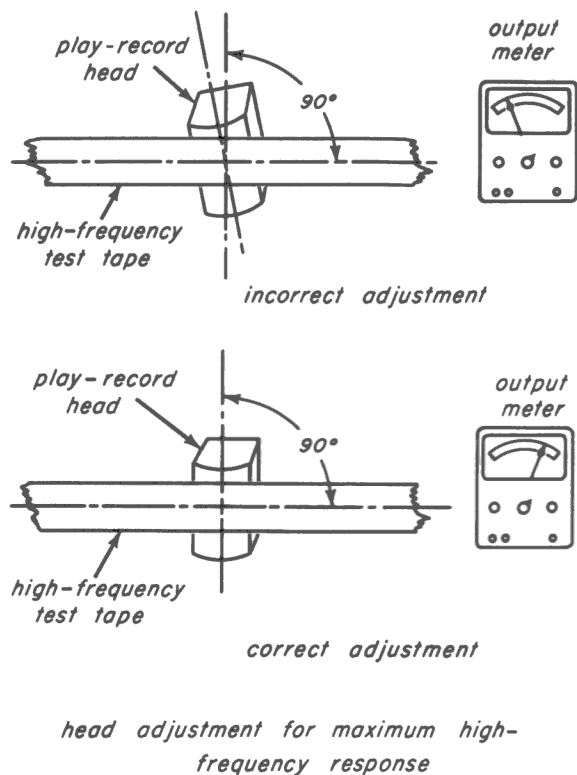


Fig. 23-33

Another adjustment that tape recorders require is calibration of the recording level indicator. The indicator may be a neon bulb, a Magic Eye[®] tube, or meter. These indicators are needed with tape recorders to show when the tape is being overloaded by the signal, but they do not indicate an overload condition, directly. All three devices indi-

cate signal strength. It is necessary to determine what strength of signal produces an overload condition and then to calibrate the indicator to show overload at that strength of signal. That is, to have the overload producing strength of signal cause the neon bulb to flash, the Magic Eye[®] to close, or the meter needle to point at a colored mark indicating overload. The total strength of signal that produces overload is not likely to be the precise strength of signal that will cause the indicator to perform as desired. Therefore, the designer of the recorder arranges the circuit to have applied to the indicator the exact portion of total overloading signal that will properly operate the indicator. The amount of overloading signal that is applied to the indicator is adjustable. To set the adjustment, an overloading strength of signal is applied to the machine. (Service notes inform you what strength of signal overloads.) Then the adjustment (a trimmer capacitor or potentiometer) is manipulated until the indicator performs to show overload.

A similar adjustment is sometimes provided to calibrate an indicator to show the normal recording-signal level.

The strength of bias flux applied to the tape is adjustable in some machines. The value of bias-signal voltage that will produce this flux is stated in the service notes, and the adjustment is manipulated to produce the required signal voltage. The voltage is read from a multimeter at a specified point in the circuit. Note that you adjust for the stated bias signal voltage and not for maximum sound. The bias value that will produce maximum sound output on playback is not the value that will produce minimum distortion. The strength of bias flux obtained by following the manufacturer's instructions for making the adjustment is a compromise, since the correct bias flux strength for minimum distortion varies somewhat from one brand of tape to the next.

The pressure pad that presses the passing tape to the magnetic head — usually a pad of felt — requires adjustment. It must be adjusted to press the tape to the head with just the right force. Too much force can slow the tape, cause the iron coating to rub off the tape, and wear down the head too

rapidly. The manufacturer's data should be consulted for the exact pressure required, and the method of measuring it and adjusting it. The following example of a manufacturer's instructions for measuring the force of a pressure pad is from the service manual for an RCA home-type recorder:

Use a pencil type postal scale and check the amount of pressure necessary to just pull the pad from the tape. The test should be made on the end of the pressure pad mounting spring Adjust the pressure for $1\frac{3}{4}$ oz. $\pm \frac{1}{4}$ oz. pressure.

Various adjustments are required to insure proper operation of the mechanical parts of a tape recorder. Parts requiring adjustment in one design may not require adjustment in another design. Manufacturer's instructions should be followed. An example of a mechanical adjustment is the brakes of our typical mechanism. If our typical mechanism were an actual machine, the brakes would have to be set to stop both the supply reel and the take-up reel at the same instant. This could be accomplished by bending the spring metal strips holding the brake shoes until both shoes contacted the drums at the same time and with equal pressure.
